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Advanced Air Conditioning Systems Developed from NASA Heat-Pipe Technology

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ADVANCED AIR CONDITIONING SYSTEMS DEVELOPED FROM NASA HEAT-PIPE TECHNOLOGY

ABSTRACT

This project exemplifies how NASA technology can be transferred to the market place in the scope of a Technology Utilization contract. In 1983, Dinh Company, a small R&D business, was trying to develop a Solar Air Conditioner. Dinh Company conceived a Heat-Pipe system to increase the dehumidification of air conditioners therefore increasing their efficiency in providing comfort in humid climates. This research work attracted the attention of the TU officers at NASA/KSC who contacted Khanh Dinh, President of Dinh Company and started negotiations which resulted in a research contract whereas Dinh Company received from NASA technical support in the fields of Heat Pipes, Photovoltaics and Power Electronics. With this infusion of new technology, Dinh Company developed in a record time: a High Efficiency air conditioner with one of the highest EER ratings today (EER:15), an air conditioning system which removes twice more moisture out of the air, a Solar Powered Heat Pump, a Photovoltaic Tracking Generator, a line of low cost Digital Inverters. All of these products becoming commercially available in less than three year's time.

INTRODUCTION

The technology utilization program from NASA can open the doors to new, young businesses. Within NASA's library are great treasures, great wealth of knowledge awaiting to be put to daily use, when the right people happen to get together to initiate a creative effort. This paper will illustrate a case of productive technology transfer in the fields of advanced air conditioning using heat-pipe technology, solar photovoltaic technology and power electronics. The work described hereafter is performed by the NASA Kennedy Space Center and Dinh Company of Alachua, Florida.

A THREE-YEAR R&D PARTNERSHIP

Dinh Company is the typical small business founded to develop innovative products for the market place comprising of a small staff of eight people with varied skills in electronics, HVAC and machining. The facilities of Dinh Company are located in Alachua, Florida near the Progress Center of the University of Florida. The manner in which NASA got involved is worth reporting; in 1983, I happened to build for the Floria Solar Energy Center a special air conditioning machine with the special capability to

efficiently dehumidify the air. Because of the humid weather of Florida, in order to achieve the high dehumidification, I invented a heat exchanger using heat-pipes between the warm air returning from the house and the cold air leaving the evaporator going to the house. The problem is that between those air streams there is very little difference of temperature and to achieve any sizable heat transfer, the heat exchanger must be extremely effective. Heat pipes seem to offer the ideal solution. I built such a machine for the Florida Solar Energy Center in late '82. The prototype tested out quite well providing twice more moisture removed than original A/C. The research done in dehumidification at FSEC caught the attention of the engineers from NASA/KSC and Mr. Reed Barnett, who was the TU officer at that time, contacted us and came to visit Dinh Company. During his visit we showed him our research projects in advanced air conditioning using solar energy. Mr. Barnett saw in our work several areas where NASA has great knowledge and experience namely the fields of heat-pipes, photovoltaics, and power processing. In the space program heat-pipes have been extensively used to dissipate heat from space vehicles, photovoltaics have been powering satellites for years and the work of Frank Nola from NASA on what is known as the Nola power factor controller is a proven way to save energy in electric motors.

At the outcome of several meetings, Dinh Company submitted a joint research project involving three years of efforts and it is the result of that program which I would like to present today. I will present to you successively the new products our company came up with in air conditioning, solar energy, and power electronics. About our newest air conditioner dehumidifier, I believe we have just beaten the world record of efficiency for a water-to-air haat pump with a certified EER: 15.34 recorded in February of 1987 by the ARL laboratories in Miami, Florida. This same heat-pump also provided an increase in moisture removal capacity of 98% with the heat-pipes activated compared to the same machine without the heat-pipe operating in the conventional manner. That is practically doubling the amount of moisture removed. The implication of such a product is enormous. Most air conditioners available on the market place today only have an EER of 7 or 8. If they were all replaced with the high efficiency dehumidifier air conditioner, half of the energy used in air conditioning can be saved and since each summer state of Florida spends as much as 30% of its electric energy to power air conditioners, this represents a total savings of 15% in all the electricity used! Not only that, the new dehumidifier-air conditioner provides an unsurpassed level of comfort due to the dryness of the air which makes the human body feel cool and light, and eventually would provide a more healthy environment for all the hot and humid regions. The applications are not limited to the boundaries of the USA where all the southern states

could benefit from this invention, but foreign countries with tropical weather would also be a prime market. The most beautiful thing about this new concept in air conditioning is that because of the fact that dry air makes you feel more comfortable at higher temperatures, homes do not need to be kept at 72 or 74 F: with the new macine 80 F feels very nice and if the air conditioning plant is designed to run at 80 degrees indoor temperature rather than 75, the compressor can be substantially smaller. As the compressor is smaller, it is less expensive and the lesser cost of the compressor usually makes up for the cost of the heat-pipes. We have invented thus a new air conditioning system which costs less to build as well as it costs less to use! The benefits on commercial installations are even greater whereas reheat was used; the Florida Solar Energy Center has made a study which shows a 57% saving on energy requirement for a medium sized commercial installation and substantial savings in initial cost. From the time of conception to the time the first dehumidifier air conditioner was put on the market place, only two years elapsed.

Going one step further, Dinh Company has developed a line of photovoltaic powered solar air conditioners. The experience with these machines has not been all good. The major problem encountered was that DC motors were used which included carbon brushes. The carbon brushes did not last long enough, creating continuous maintenance problems. The

troubles were reported to NASA and we were allowed to study the use of brushless DC motors. A brushless DC motor is a misnomer. Because this brushless motor is in reality a synchronous AC motor and to power such a motor one needs alternative currents. Since we started with direct current from the photovoltaics, we had to use an inverter. Looking at the market place we could not find any inverter which provides the right combination of high efficiency and low cost, so we set out to build our own. Under the scope of this project my company came up with an extraordinarily simple digital circuit costing no more than $10 in parts. The new circuity can provide variable frequency as well as variable duty cycle, features found only in highly expensive inverters. That circuitry in turn controls power MOSFETs (which are electronic switches) to send the current back and forth creating the alternative currents. The MOSFETs have the bad habit of heating intensely and once again heat-pipe technology is used to dissipate the heat from those devices resulting in a spin-off product which the power electronic industry will like to have: Heat-pipe cooler to replace heat sinks, another product Dinh Company will market very shortly by themselves. The inverters built under this scope of work costs only half as much as anything comparable on the market place and yield efficiencies as high as 95%. The new generation of solar air conditioners from Dinh Company now have hermetic compressors powered by inverters and promise to last just as long as any conventional air conditioner.

Major improvements were also done on the photovoltaic generators themselves. Whereas the common practice is to install the photovoltaic modules on a static rack, we took the problem to an engineer at KSC and asked for his advice on building a tracking mechanism to turn the photovoltaics toward the sun. If nature tracks the sun with sunflowers, why shouldn't we? The engineer shared with us his experience in designing tracking mechanisms by using a shading device on two sensors to activate a servo mechanism to turn the photovoltaic cells toward the sun. After some refining and simplifications, Dinh Company came out with a photovoltaic tracker which is totally self controlled and self powered and which is capable of carrying not only the largest amount of photovoltaic modules for any tracker in the market place but also an equivalent area of flanking reflectors. The combined results obtained with tracking and enhancing reflectors were astonishing. We were able to bring the cost of a solar electric generator down to $6 per peak watt installed, which is cheaper than some nuclear power plants. This kind of photovoltaic generator will be a great blessing for the third world countries for irrigation, communication and health programs. NASA technology has brought to earth a new source of inexhaustible energy at a price more attractive than small diesel generators! The power electronics developed for the solar air conditioner and the brushless motor rather than running air conditioners the photovoltaic generators and digital inverters can also

be used to irrigate innumerable places in the world to produce food and maybe open a new era of peace and prosperity closer to us the same inverters when coupled with the phase shift sensing circuit designed by Frank Nola from NASA can become the basis to a new line of electricity saving controls to be used on all induction motors.

CONCLUSION

As we perfected the high efficiency dehumidifier air conditioner we received many inquiries from drier regions which could not benefit from this invention. However, we thought of another way to use heat-pipes to assist evaporative coolers. In places such as Arizona, New Mexico, and Nevada the relative humidity of the air can drop to less than 10% and evaporating water can create fairly cold temperatures. That is the principle behind evaporative coolers. Although evaporating water to create cold air is extremely energy efficient, evaporative coolers introduce into the houses large amounts of moisture. In order to obtain the cold but avoid the moisture, a heat exchanger can be used. And, once again, heat-pipes would be perfect for such an application where only a small difference of temperatures exists. We designed a hybrid kind of evaporative cooler with a topping vapor compression which holds great promises for saving even more energy in dry climates than the dehumidifier air conditioners in humid

climates. A modeling of the new hybrid cycle shows savings of 50% would be quite feasible. Going to the colder regions with high humidity, such as Oregon, we found a third use for heat-pipes, but this time to provide heating. The principle relies on chemical dessicants to absorb water vapors from the cold air liberating the latent heat of condensation and creating high temperatures. Those high temperatures unfortunately are accompanied by very dry air which is unhealthy to human needs and, there again, we used the heat-pipes to transfer the heat into the house without admitting the dry air. The cycle is completed by a regeneration of the dessicant with a heat source such as gas burning. My research has shown no antecedent to this new heating concept which I would name "regenerative latent heat-pump". This new concept in heating theoretically can yield savings greater than 50% in comparison to the best gas furnaces. At Dinh Company we believe that this is just the beginning of an extraordinary venture in high technology, a venture in which NASA is a very valuable partner.